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Parameters Used With Diode Lasers (808-980 nm) in Dentin Hypersensitivity Management: A Systematic Review

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Abstract

Introduction: The present study aimed to describe parameters used with 808- to 980-nm wavelength diode lasers for managing dentin hypersensitivity and analyze their results.

Methods: The inclusion criteria were based on randomized controlled clinical trials using diode lasers at an 808-980 nm wavelength range in patients with dentine hypersensitivity with a minimum of 1-month follow-up. An electronic search for articles on Medline, PubMed and Cochrane databases was performed. The risk of bias was assessed with the Cochrane collaboration tool.

Results: Our electronic search resulted in 130 papers, of which 11 articles met the inclusion criteria. A majority of the studies assessed dentine hypersensitivity using the Visual Analogue Scale, which ranged between 2.3 and 8.8 before treatment and significantly reduced to a mean value of 0.45-3.7 after diode laser application. The power settings ranged between 1.5 mW and 3 W with an emission mode of continuous wave, except for 2 authors who used chopped mode. The energy density varied from 2.5 to 128 J/cm^2, and the exposure time was between 10 and 120 seconds. The authors applied a minimum of 1 to 4 treatment sessions with a 2-day to 1-week interval between them. Most of the studies mentioned the tooth surface as the treatment site but without describing the specific irradiation points.

Conclusion: Despite the heterogeneity of the analyzed variables, a statistically significant improvement in all laser groups was described. However, they cannot be compared homogenously.

Keywords: Dentin hypersensitivity; Diode laser; Laser therapy; Dentistry.

Introduction

After active periodontal treatment, gingival recession and root exposure can lead to the development of dentine hypersensitivity (DH). It is defined as pain derived from exposed dentine in response to chemical, thermal, tactile, or osmotic stimuli that cannot be explained as arising from any other dental defect or pathology.[1] Brannstrom's hydrodynamic theory is the most accepted explanation of DH and states that fluid movement in dentinal tubules is provoked by different stimuli that can cause pain.[2] It is most prevalent in patients aged between 20 and 40 years, with higher prevalence in females and in 60% to 98% of patients with periodontal disease.[3,4] Many treatment approaches for root sensitivity have been investigated, with variable results; however, no single therapy can reduce pain to satisfactory levels. Topical desensitizing agents are the most commonly used treatment, both in an office and for home care. Over the last decades, laser treatment has been introduced for managing this clinical condition. A diode laser with different wavelengths and parameters is a commonly used procedure, and also several studies have shown good results.[5-7] Nevertheless, no specific wavelength has been proven to manage DH best. Furthermore, different treatment approaches involving diode lasers have been utilized to create photobiomodulatory effects that reduce pain and inflammation[8,9] or to occlude mechanical tubules by melting dentine through the thermal effect produced by laser irradiation. Laser treatment can be used by either direct application, involving irradiation over the area affected, or indirect irradiation, preceded by the application of chemical agents such as sodium fluoride or stannous fluoride (SnF_2), leading to occlusion of the melted dentine through the laser's thermal effects.[1] Other lasers such as neodymium-doped yttrium aluminium garnet (Nd:YAG) and erbium chromium yttrium scandium gallium garnet laser (Er,Cr:YSGG) lasers have also been investigated for treating DH through superficial dentine melting and dentinal tubule occlusion,[10] but the long-term efficacy of this approach is controversial.

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The objectives of this review are to describe the different parameters of 808- to 980-nm wavelength diode lasers for managing DH according to the literature and to analyze the results.

Materials and Methods

Study Protocol

This systematic review was conducted according to the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) guidelines. We focused on the following question: Does the literature, to date, provide the optimum diode laser parameters with which superior results in treating DH can be achieved?

Eligibility Criteria

The population, intervention, comparison, outcomes (PICO) process was used to answer the previously mentioned focused question:

- Population: Individuals older than 18 years with DH.
- Intervention: High- or low-intensity diode laser therapy alone or in combination with desensitizing agents for pain reduction.
- Comparison: Lack of diode laser therapy or placebo (if applicable).
- Outcomes: Pain reduction after therapy with stability up to 30 days.

Inclusion and Exclusion Criteria

The inclusion criteria included randomized clinical trials, with or without control or placebo groups, in which a diode laser was used from wavelengths in the infrared electromagnetic spectrum ranging from 808 to 980 nm, with a minimum follow-up of 30 days after treatment.

Articles that were not written in English, case reports, pilot studies, narrative literature reviews, letters to the editor, and in vitro studies were excluded.

We focused our review on diode lasers in the wavelength range of 808 nm to 980 nm due to the increased incorporation of these laser devices into clinical practice for multiple uses, such as soft tissue surgery, adjunctive therapy in endodontic and periodontal treatments, and applications like photobiomodulation.

Study Selection and Data Extraction

Two authors conducted an electronic search in MEDLINE (PubMed and Cochrane) for articles published from 2009 until 2020. An advanced search in PubMed resulted in 25 articles when using the following MESH terms: (((((“dentin desensitizing agents/therapeutic use”[Mesh]) OR (“dentin sensitivity/drug therapy”[Mesh] OR “dentin sensitivity/etiology”[Mesh] OR “dentin sensitivity/prevention and control”[Mesh] OR “dentin sensitivity/therapy”[Mesh])) OR “dentin sensitivity”[Mesh]) AND “lasers, semiconductor/therapeutic use”[Mesh]) OR “low-level light therapy”[Mesh]) OR “lasers, semiconductor”[Mesh], filters: clinical trial, meta-analysis, randomized controlled trial, systematic review, humans, English, dental journals. An advanced search with the following terms included in the title resulted in 17 papers: ((((((Dentin Desensitizing[Title]) OR (dentin hypersensitivity[Title])) OR (desensitization of teeth[Title])) AND (diode laser[Title])) OR (GaAlAs laser[Title])) OR (LLLT[Title])) OR (low-level light therapy[MeSH Terms]), filters: clinical trial, meta-analysis, randomized controlled trial, systematic review, humans, English, dental journals. Another 9 articles were found with a regular search of all journals using the following keywords: (dentin hypersensitivity GaAlAs lasers diode laser Low-level laser, filters: clinical trial, meta-analysis, randomized controlled trial, systematic review, humans, English).

The Cochrane Database was searched using titles, abstracts, and keywords for trials matching the following: dentin hypersensitivity in Title Abstract Keyword AND diode laser in Title Abstract Keyword OR low-power laser in Title Abstract Keyword (word variations were also searched), with a custom publication range from 2009 to 2020. Selecting only indexed papers in PubMed and Embase resulted in 130 total papers. After manual selection, 48 articles were included for screening, and following our inclusion criteria, 11 papers were included for our final review. There was no disagreement on study selection and inclusion

The variables analyzed in these articles were mean age group, follow-up period, testing type and assessment of the treatment outcomes, number of treatment sessions, interval between sessions, wavelength used, emission mode, irradiation protocol (including power and site irradiation), laser probe or tip used, energy density, and exposure time (Supplementary file 1, Table S1).

Two authors assessed the risk of bias by following the Cochrane Collaboration tool (Figure 1).

Results

A total of 48 articles appeared in the electronic research, of which 12 studies were eligible for full review. One study was excluded due to uncertain randomization being suspected, and the remaining 11 met all of the inclusion criteria (Figure 2).

Subject Inclusion and Exclusion Criteria in the Studies

Common inclusion criteria for the patients in the reviewed papers included patients with DH, who were older than 18 years old, with good systemic health, presenting or not presenting gingival recessions, and pain visual analogue scale (VAS) values ≥ 2. Among the exclusion criteria used by the authors were teeth with large defective restorations, the presence of cracked enamel, teeth mobility, severe calculus accumulation, active periodontally or endodontically related lesions, the presence of a fixed

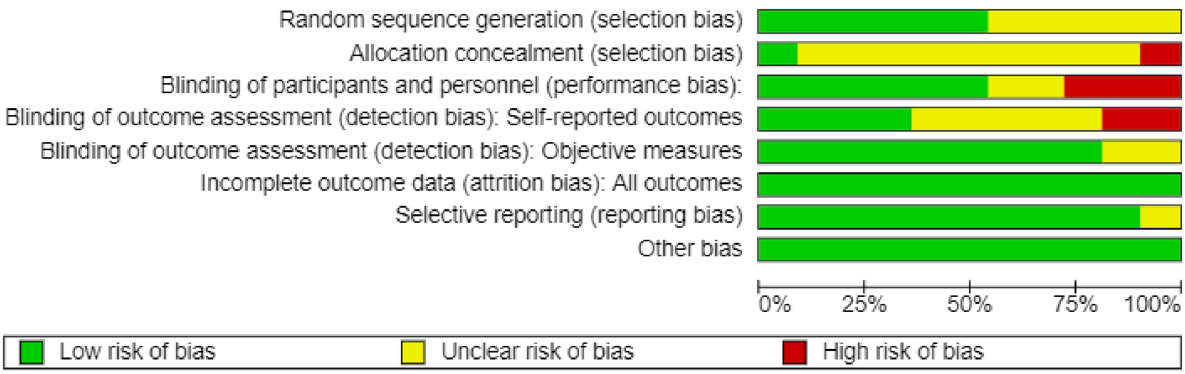

Figure 1. The Risk of Bias Summary, Review of Authors´ Judgments About Each Risk of Bias Item Presented as Percentages Across All Included Studies.

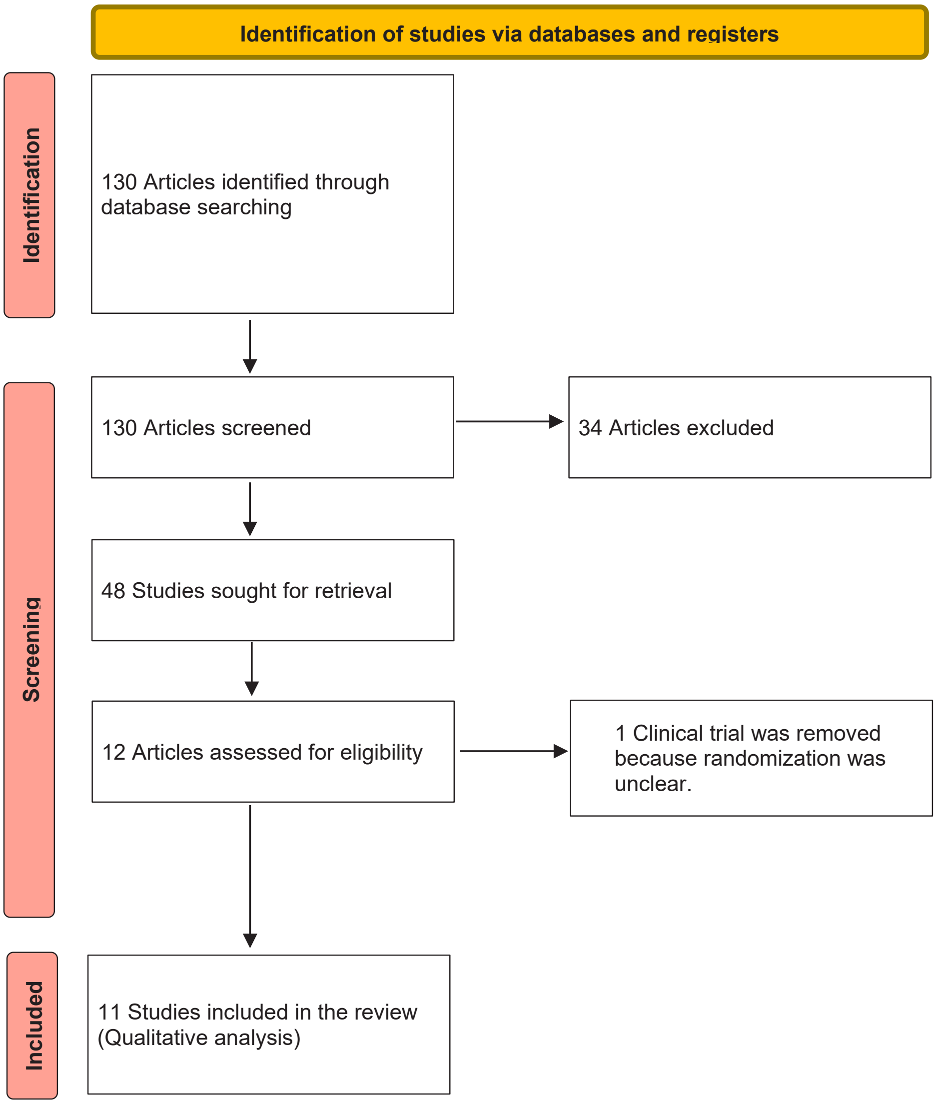

Figure 2. Prisma Flow Chart.

orthodontic appliance, any professional desensitizing therapy applied in the last 3-6 months, use of home-care desensitizing toothpastes, and patients currently using medications (such as antidepressants, antihistamines, anticonvulsants, sedatives, and nonsteroidal anti-inflammatory drugs).

The selected studies included patients aged between 18 and 70 years. In more than 50% of the articles, the mean age was around 40 years (range of 25 to 45).

Pain-Assessment Methods

Before applying the treatment, the authors subjectively evaluated the degree of DH. Four of the 11 articles[1,11-13] used the thermal-evaporative test, while 5 others[8,14-17] combined it with a tactile stimulus test, 1 study added a thermal test,[18] and 1 study[19] did not mention the exact test done. All of the studies used an analogical numerical scale such as a numerical rating scale (NRS), verbal rating scale (VRS), or the most commonly used scale called a VAS.

Among the laser groups found in the reviewed papers, the baseline VAS ranged between 2.3 and 8.8. These values dropped after laser application to 0.45-3.7, with the results being statistically significant in all of them.

Wavelengths

The wavelengths used for the diode lasers ranged from 808 to 980 nm. Seven of the 11 studies [8,11-13,15,18,19] used wavelength values of 808-810 nm in an attempt to achieve low-intensity laser effects due to their deeper tissue penetration than lasers at higher wavelengths. The remaining four studies[1,14,16,17] chose maximum ranges from 940 to 980 nm, intending to produce superficial dentin melting in combination with higher-intensity parameters.

Power Settings and Irradiation Time

The power settings used in seven studies[8,11-13,15,18,19] were between 1.5-100 mW and 1 W, with a wavelength range of 808-810 nm. The remaining 4 articles[1,14,16,17] utilized settings between 0.3 W and 3 W in wavelength groups of 940 and 980 nm. Treatment time ranged from a minimum of 10 seconds to a maximum of 120 seconds. Different laser probes and fiber tips were used, ranging from 300 µm to 2 cm in diameter.

Energy Density

The calculation of the energy density depends on all of the previously mentioned parameters (power, time, and area in cm^2). Due to its heterogeneity in the reviewed articles, we found energy density values ranging from 2.5 to 128 J/cm^2.

Emission Mode

In more than 50% of the included studies, continuous mode (CW) was used, and only two authors[14,16] applied chopped mode using the same wavelength (980 nm).

Irradiation Site

Two studies[8,11] provided detailed descriptions of the irradiation site, specifically at four points (the mesial, distal, cervical, and apical regions). Two studies[1,17] stated that the authors irradiated the cervical area, while the rest of the studies mentioned the tooth surface as the treatment site. The studies applied from 1 to 4 treatment sessions, with a 2-day to 1-week interval between them.

Discussion

DH treatment is aimed at reducing fluid flow by occluding dentinal tubules and/or desensitizing nerves. It can be achieved by chemical means, such as using potassium-based agents, which promote an increase in potassium ion concentration in odontoblastic endings, thus reducing sensory stimulus conduction. Other agents such as resin sealants or bonding agents can precipitate proteins and inorganic crystals which results in dentinal tubules occluding.[20,21]

The laser treatments proposed by the literature involve either physically melting the exposed dentine blocking the dentinal tubules[22,23] or using the photobiomodulatory effect.[11] A low-intensity laser can induce an analgesic effect by changing C-fiber depolarization, thus increasing the amplitude of cell membranes' action potential, which can relieve pain.[24] Tissue response after laser irradiation is affected by wavelength, output power, radiation mode, and dose.[25]

Regarding the number of sessions, Joshi et al[26] suggested that using multiple applications can increase the produced effect, but this is still controversial in clinical studies following a variety of protocols, without agreement on a specific argument. As a result, there is no consensus on the recommended effective number of sessions.

Concerning the wavelengths, the extracted data from the reviewed studies showed the following application parameters. Two studies mentioned 808 nm. In a randomized single-blinded study, Moura et al[11] compared laser application to 2 desensitizing agents, finding positive results in all groups. In 6 randomized controlled clinical trials,[8,12,13,15,18,19] using 810 nm with low-power values achieved photobiomodulatory effects, with all of the studies showing positive results. One of the studies[11] used 4 sessions, another study[8] used 3, and the rest applied only 1, with all of them achieving the same results as well as long-term stability after 2 and 6 months. The study by Narayanan et al[18] was the only study that compared the treatment outcomes in fluorotic versus non-fluorotic teeth, obtaining better results in the fluorotic group, which the authors attributed to the more porous nature of the tooth structure in fluorotic teeth, which allows for better desensitizing in combination therapy. However, the difference was not statistically significant.

Tabibzadeh et al[14] used 980 nm in 2 randomly distributed groups—high-intensity and combined high- and low-intensity laser settings—but found no significant difference between both groups. Umberto et al[16] applied the same wavelength but used 0.5 W in chopped mode, in combination with NaF, seeking superficial melting and dentinal tubules occlusion. Their combined therapy showed better results.

Raut et al[1] conducted a randomized controlled clinical trial combining stannous fluoride (SnF_2) with a 940 nm diode laser, using 0.8 W. They found no statistically significant difference between the laser alone versus combined treatment. Nevertheless, both groups showed significant improvement as compared to the control group. Using the same wavelength, Pourshahidi et al[17] compared diode laser treatment at 0.4 W and energy density of 2.5 J/cm^2 for 10 seconds to the Er,Cr:YSGG. Both groups showed favorable results, with more long-term stability among the Er,Cr:YSGG group.

We did not have clear evidence concerning either the best wavelength for diode lasers specific to treating DH or the best approach for achieving either photobiomodulatory effects or superficial melting and dentinal tubule occlusion. Nevertheless, it seems that the revised articles tended to use lower wavelength ranges to produce photobiomodulatory effects, due to their higher tissue penetration, but higher ranges for photo-thermal effects and superficial dentine melting.

Regarding irradiation protocols, Liu et al[27] demonstrated that using 2 W and fluence of 166 J/cm^2 is adequate for using a 980 nm wavelength to seal dentinal tubules without excessive dentine melting, in accordance with results from the revised articles using the same wavelength and a power range from 0.5 W to 3 W.[13,18] On the other hand, articles reporting 808 and 810 nm wavelengths applied low-power ranges between 1.5 mW and 100 mW to obtain photobiomodulatory and analgesic effects, which are affected by exposure time and irradiation area. The use of a power meter is highly recommended for researchers to confirm the actual power delivered and to increase the reliability of the treatment parameters, yet only 1 study used a power meter.[11] The literature lacks data explaining the rationale of using the combination of the different power settings with those wavelengths. However, it seems that researchers prefer using lower power at a wavelength range of 808-810 nm to achieve photobiomodulation due to its deeper tissue penetration, and for those who used wavelength between 940 and 980 nm tends to apply higher power to achieve superficial dentine melting.

The irradiation time can affect the therapeutic effect, even while maintaining the same fluence, by adjusting the power settings according to the third law of photobiology.[28] We found no agreement concerning the minimum exposure time to achieve stimulatory or inhibitory effects in the reviewed articles. What we know, as stated by Arndt Schultz's law,[29] is that doses between 0.01 and 10 J/cm^2 are stimulatory; beyond this, exposure can result in inhibitory effects, which can be translated into analgesia. Some authors irradiated for between 60 and 120 seconds to achieve an inhibitory effect.[1,12]

The treatment fiber tip or laser probe used is another important factor that can change the dose calculations, in terms of energy density, because the area can vary greatly. Two studies[1,12] used tip diameters of 2 and 3.5 cm respectively. The former irradiated at a 2-mm distance and did not indicate any type of movement, while the latter performed a sweeping motion in defocused mode. Narayanan et al[18] used a bleaching tip at a 1-mm distance. One author did not indicate the tip used,[13] and the remaining 7 studies indicated a scanning or sweeping movement with a fiber tip diameter ranging from 300-400 microns in noncontact mode.[8,11,14-17,19]

The emission mode can be either CW or pulsed mode. Nevertheless, "chopped mode" can be a more precise term to use with diode lasers. In high-intensity laser applications, a chopped mode can help to achieve higher power settings without overheating the treated area, while its role is not yet clear in low-power parameters. Among the articles reviewed, only 2 studies applied chopped mode using low-power settings (of 0.2 and 0.5 W).[14,16] Keshri et al[30] conducted an animal study using an 810 nm wavelength to study its photobiomodulatory effect on wound healing. They compared CW and 2 pulse modes, and they found superior results with 10 Hz on cytochrome C oxidase and more adenosine triphosphate production than when using CW or 100 Hz pulse duration. Further well-designed clinical trials are necessary to determine the best emission mode for its effects on the pulp tissue. Reporting laser parameters insufficiently can make dose calculations and study reproducibility difficult. Hamblin et al[31] suggested the need for an example table showing the laser-reporting parameters for an article to be considered reproducible and from which dose calculations can be made easily and precisely.

Conclusion

The variables could not be compared homogenously due to the heterogeneity of the studies reviewed, in terms of the laser parameters, the mechanism of laser application, and the number of sessions applied. However, all of the included studies showed a statistically significant improvement in treatment outcomes among the laser groups. Additional randomized controlled clinical trials in patients receiving DH are recommended. These should use different diode laser wavelengths while holding the other parameters constant, such as energy density, pre- and post-treatment numerical evaluation scale, number of sessions, application points, emission mode, and exposure time, to be able to determine the best diode infrared wavelength for this type of alteration.

Conflict of interests

The authors declared no conflict of interest for the elaboration of this paper.

Ethical Considerations

Not applicable.

Supplementary files

Supplementary file 1 contains Table S1.

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